MATERIALS

ELASTOMERS

Elastomers are polymers that have the ability to recover within 10% of their original length after being stretched 100% for five minutes.

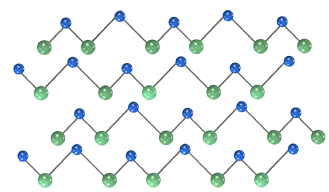
A polymer is a macromolecule consisting of a repeated chain of smaller units. Based on their behavior when exposed to heat, polymers can be divided into two catagories, thermoplastics and thermosets.

The macromolecules in thermoplastics are entangled and not interconnected. They can be melted and reformed without significant impact to mechanical properties. Thermoplastics have good ductility and formability.

The macromolecules in thermosets are closely intertwined and are interconnected. Thermosets undergo chemical cross-linking during hardening that is irreversible. This prevents them from being remolded or recycled.

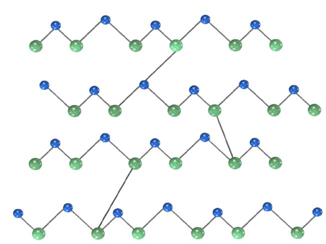
Elastomers are commonly refered to as either natural or synthetic rubber. Natural rubber comes from latex, a milky colloid produced by some trees (especially trees of the genera Hevea and Ficus). To harvest the latex a diagonal incision is made in the bark of the tree, the latex begins to flow through the incision and is collected in buckets at the base of the tree.

All of the elastomers discussed here are synthetic rubbers which are compounds comprised of several constituents. These elastomers are a mix of a base polymer and other chemicals that are used to improve mechanical properties through a vulcanization process.



Thermoplastics.

Macromolecules in thermoplastics are entangled and not interconnected.



Thermoset.

Macromolecules in thermoset are closely interwined and are interconnected.

Vulcanization is a chemical process induced by heating rubber with vulcanizing agent (such as sulfur). Vulcanized rubber has higher tensile strength and is more resistant to swelling and abrasion. A typical elastomer compound may be composed of the following elements:

Natural rubber.

Comes from latex, a milky collaid produced by some trees.

- Base polymer: Can be natural rubber or synthetic polymers. Natural rubber has a higher tensile strength and resistance to fatigue, while synthetic rubber offers better resistance to abrasion, heat and the effects of aging.

- Fillers: Fillers are used for two main reasons, to improve the mechanical properties of the material (such as tear strength, tensile strength, abrasion resistance and modulus of elasticity) or to reduce cost. Carbon black and silica are the most common reinforcing fillers. Carbon black provides better modulus and resistance to abrasion than colloidal silica. The smaller the particle size, the greater the observed reinforcing effect.

- Plasticizers: Plasticizers improve the flow of the rubber during processing and improve the low temperature properties of the vulcanizate. The most common plasticizers are esters, pine tars and low molecular weight polyethylene.

- Vulcanizing agents: The most common vulcanizing agent is sulfur, but peroxides, urethane crosslinkers, metallic oxides and acetoxysilane are also used.

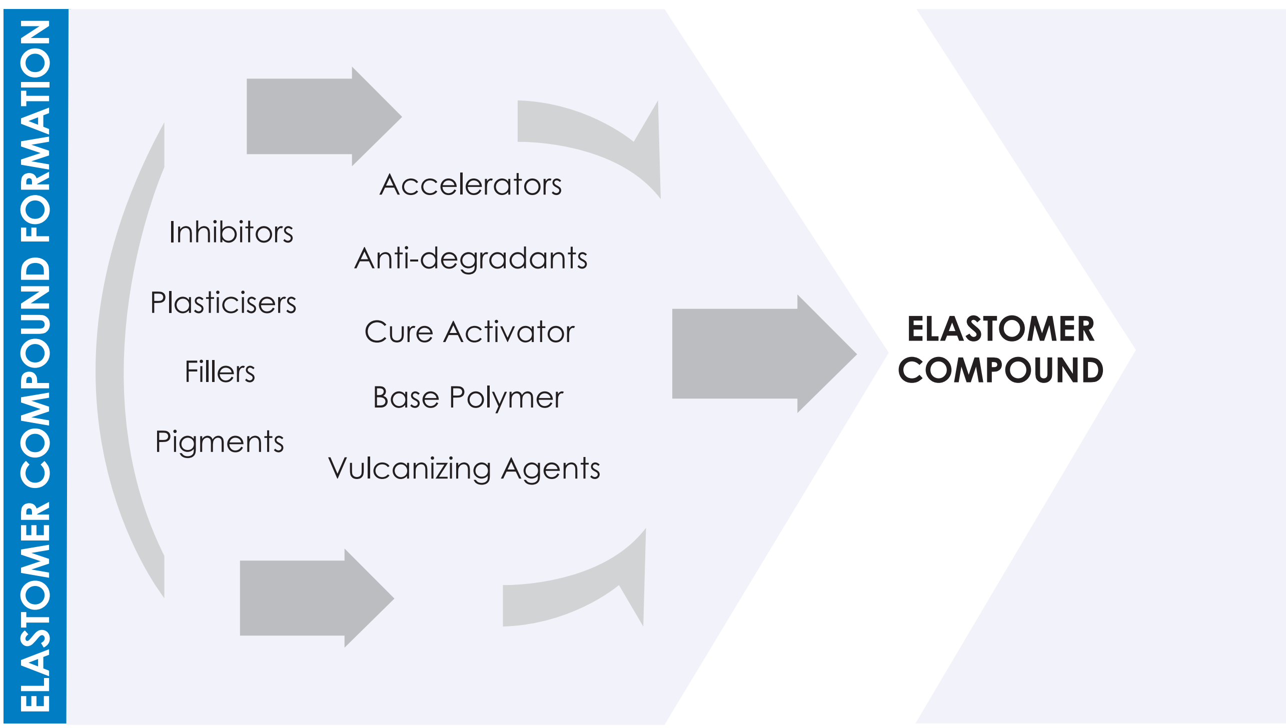
- Accelerators: Accelerators increase the rate of the cross linking reaction and cross linking density, without affecting the properties of the elastomer. The effect of a combination of accelerators is stronger than the added effects of the individual components.

- Cure activators: are used to start vulcanization and promote crosslinking and cure. The two most common activators are zinc oxide and stearic acid.

- Inhibitors: When the temperature increases the reaction rate increases as well, inhibitors are added to force a slower chemical reaction during the vulcanization process.

- Anti-degradants: Anti-degradants increase resistance to the environment. Common anti-degradants include antioxidants and antiozonants which help the elastomer resist degradation from ozone, UV light and oxygen.

- Pigments: Pigments, organic and inorganic, are used to color the material.



Elastomer Compound.

A typical elastomer compound may be composed of these elements.

THE EVOLUTION OF RUBBER

- In 1731 Charles Marie de La Condamine, a French geographer and mathematician, set out on an expedition to South America. In 1736 while in route to Quito, Ecuador La Condamine became the first westerner to encounter rubber. He also coined the term "latex".

- In 1770 Joseph Priestley discovered that rubbing the material over pencil marks on paper would erase them, and thus originated the name "rubber".

- In 1791 Samuel Peal patented a method that made fabric waterproof by treating it with rubber.

- In 1823 Charles Macintosh founded a factory that made rainproof cloth and fabrics using rubber.

- In 1834 Friedrich Ludersdorf and Nathaniel Hayward discover that adding sulfur to the rubber made it less sticky.

- In 1839 Charles Goodyear discovered that adding sulfur to rubber and then heating it made it retain its elasticity, this process is known today as vulcanization.

- In 1860 Charles Hanson Greville Williams discovered that natural rubber was an isoprene monomer, this was a fundamental discovery for the development of synthetic rubber years later.

- In 1877 Chapman Mitchell started working with sulfuric acid to recycle rubber into new products.

- In 1905 Arthur H. Marks invented the alkaline recovery process, and the first rubber factory laboratory was founded.

- In 1906 George Oenslager discovered that adding accelerators to the vulcanization process would reduce the heating time for curing by 60 – 80%, improving the properties of the rubber.

- In 1926 German scientist G. Ebert succeeded in producing a sodium-polymerized rubber from butadiene that would become the predecesor to nitrile.

- During World War II the supply of natural rubber was greatly depleted, this accelerated the development of synthetic rubber leading to many of the compounds used today.

With the development of synthetic rubbers the mechanical properties of the materials could be significantly improved. Today the use of synthetic rubber in industry is common place and can be found in many products such as radial shaft seals.

MATERIAL PROPERTIES

Elastomers are a versatile product used in a wide range of applications. When selecting a compound there are a number of physical properties that should to be considered:

- Hardness: The measure of a material's resistance to deformation by surface indentation. The typical measuring system for elastomers is the Shore durometer. The A scale is used for soft elastomers, while the D scale is used for harder elastomers. The ASTM specification for the durometer hardness test method for rubber is ASTM D2240.

- Tensile strength: The amount of force required to fracture a rubber specimen while applying tensile force along it. In the metric system it is measured in MPa (megapascals) and in the English System it is measured in psi (pounds-per-square-inch). The ASTM specification for tension test methods for vulcanized rubber and thermoplastic elastomers is ASTM D412.

Hardness Tester.

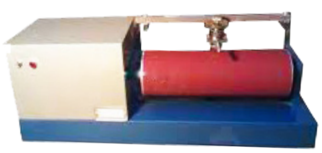
Measure of a material's resistance to deformation by surface indentation.

Tensile Strength Machine.

Amount of force required to fracture a rubber specimen while applying tensile force along it.

Tear Resistance Tester.

The capacity of a material to resist the growth of a cut when tension is applied.



Abrasion Resistance Tester.

Amount of material lost due to wear by the contact of a moving part.

- Elongation: The percentage that the rubber specimen will deform before braking when a tensile force is applied.

- Modulus: is the stress required to produce a given force. Higher modulus = less extrusion. It is measured in MPa.

- Tear resistance: Is the capacity of a material to resist the growth of a cut when tension is applied. It is measured in kN/m (kilonewtons per meter) for the metric system or in lbf/in (pounds force per inch) for the English system. The ASTM specification for tear strength of conventional vulcanized rubber and thermoplastic elastomers is ASTM D624.

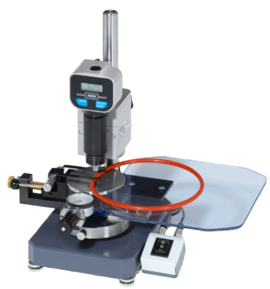
- Abrasion resistance: Is the amount of material lost due to wear by the contact of a moving part.

- Flexibility: The resistance of the material to a bending force without being damaged.

- Adhesion: Ability of the material to cling to the metallic case. The ASTM test method for adhesion to rigid substrates is ASTM D429.

- Compression set resistance: The percentage of the original specimen thickness after axially directed pushing forces are applied and released over a set temperature and time. The ASTM specification for compression set is ASTM D395.

- Resilience: The ability to absorb temporary energy without creating a permanent distortion. The ASTM specification for resilience is ASTM D945.



Compression Set Tester.

Percentage of the original specimen thickness after axially directed pushing forces are applied.

Resilience Tester.

Ability to absorb temporary energy whitout creating a permanent distortion.

MATERIALS PROFILES

Selecting the elastomer material for a radial shaft seal is important because it has to ensure that it satisfies all of the requirements for the application, without increasing the cost.

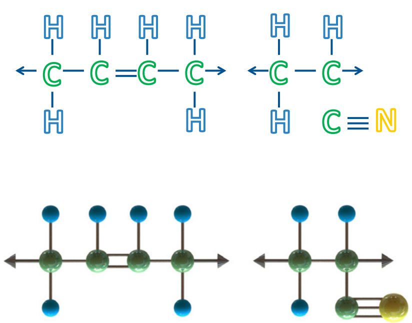
There are differents materials that are used to make radial shaft seals the most common materials use by ESP International are the following:

- Nitrile (N)
- Hydrogenated Nitrile (H)
- Fluoroelastomer (F)
- Polyacrylate (P)
- Silicone (S)
- Polytetrafluoroethylene (PTFE)
- Ethylene Propylene Diene Monomer (E)
- Chloroprene (C)
- Polyurethane (AU)

Temperature Range.

Temperature range of Nitrile

NITRILE



Molecular Structure of Nitrile.

Nitrile is the combination of butadiene and acrylonitrile.

MATERIALS

NITRILE or BUNA N or NBR

Low cost, temperature range -40° to +250° F, most commonly used elastomer. Shelf life 3 to 5 years

ASTM D2000/ SAE J200 Type/Class – BF, BG, BK or CH classifications.

ASTM D1418 Designation NBR, XNBR

ARP 5316 Shelf life 15 Years

Nitrile is the combination of butadiene (provides elasticity and low temperature flexibility, creates resistance to heat, chemicals and oxidation) and acrylonitrile (provides hardness, tensile strength and creates resistance to abrasion, fuel and oil). A standard general-purpose nitrile compound usually contains 34% ACN (Acrylonitrile).

ACN ranges from 18% to 50%. While incrementing the ACN content, the high temperature properties improve but it also affects the low temperature properties.

Advantages: Excellent tensile strength, abrasion, tear and compression resistance. It is used in water and steam applications (below 212° F), petroleum oils and fuels, silicone oils and greases, propane, ethylene glycol, butane, vegetable, mineral oils and greases, dilute acids.

Disadvantages: Low resistance to ozone, sunlight and weathering. Incompatible with benzene, toluene, xylene, halogen derivatives (carbon tetrachloride, trichloroethylene), ketones (MEK, acetone), phosphate ester hydraulic fluids (Skydrol, Pydraul), strong acids, glycol.

HYDROGENATED NITRILE or HNBR or HYDROGENATED NITRILE BUTADIENE RUBBER

High cost, temperature range -25° to +300°F

ASTM D2000/ SAE J200 Type/Class DH

ASTM D1418 Designation None

MIL-HDBK-695 Shelf life 15 Years

Hydrogenated Nitrile comes from adding hydrogen to the nitrile molecular chain to make it more stable. The addition of hydrogen reduces the number of carbon-carbon double bonds, making it less reactive.

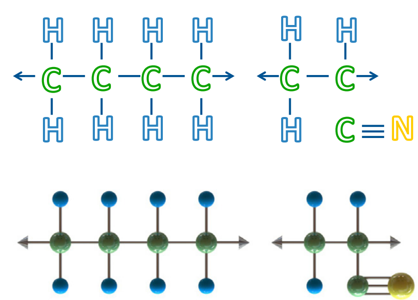
Advantages: In comparison with NBR, HNBR has better abrasion resistance, tear resistance, high temperature properties and resistance to chemical attacks. It can be used in ozone applications, R134a refrigerant gas, petroleum oils and fuels, water and team (up to 300° F), silicone oils and greases, vegetable and animal fats and fluids.

Disadvantages: Cannot be use in chlorinated hydrocarbons, polar solvents (esters and ketones), and strong acids.

Temperature Range.

Temperature range of Hydrogenated Nitrile

HYDROGENATED NITRILE



Molecular Structure of Hydrogenate Nitrile.

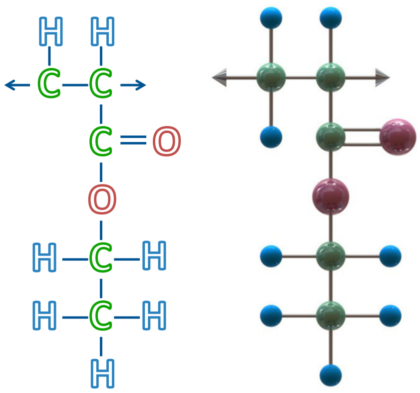
The addition of hydrogen reduces the number of carbon-carbon double bonds, making it less reactive.

POLYACRYLATE or ACM

Temperature Range.

Temperature range of Polyacrylate.

POLYACRYLATE



Molecular Structure of Polyacrylate.

Are copolymers of ethyl or butyl acrylate with a combination of chlorine, acid, amide or epoxy compounds.

Medium cost, temperature -25° to +275°F

ASTM D2000/ SAE J200 Type/Class – DF, DH or EH

ASTM D1418 Designation ACM

MIL-HDBK-695 Shelf life 20 Years

Polyacrylate are copolymers of ethyl or butyl acrylate with a combination of chlorine, acid, amide or epoxy compounds.

Advantages: Resistance to petroleum fuels and oils, automatic transmission fluid, type A power steering fluid. Good resistance to mineral oil, sunlight, oxygen and ozone.

Disadvantages: Cannot be used in alcohol, alkalis, glycol based brake fluids, EP fluids, chlorinated hydrocarbons, gear oils, glycol based brake fluids, hydrocarbons, water or steam (above 275°F), acids and amines. Lower water compatibility, cold flexibility, strength and compression set resistance than nitrile.

MATERIALS

FLUOROELASTOMER or FLUOROCARBON or FKM or VITON®

High cost, temperature -15° to +400°F

ASTM D2000/ SAE J200 Type/Class HK

ASTM D1418 Designation FKM

ARP 5316 Shelf life Unlimited

Fluorine is added to thermoset elastomers creating Fluoroelastomers. It's generally composed of vinylidene fluoride (VF2), hexafluoropropylene (HFP), containing 66% – 70% fluorine. And other components are added to improve different properties, like tetrafluoroethylene, which offers better chemical resistance and perfluoromethylvinyl ether (PMVE) which improves FKM's low temperature properties.

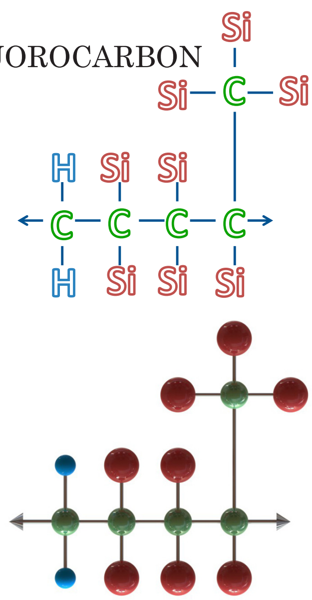
Advantages: Excellent resistance to chemicals, oil, ozone and sunlight. Can be used in petroleum oils and fuel, non flammable hydraulic fuels, acids, aircraft engine applications, synthetic hydraulic fluids, organic solvents, mineral and vegetable oil and grease, aliphatic hydrocarbons (butane, propane, natural gas), hard vacuum applications, silicone oils and greases, solvents and water or steam (up to 400°F).

Disadvantages: Cannot be used in amines, glycol based brake fluids, methanol, ammonia gas, amines, alkalis, hydrocarbons, ketones, low molecular weight esters and ethers, fireproof hydraulic fluids, formic and acetic acids.

Temperature Range.

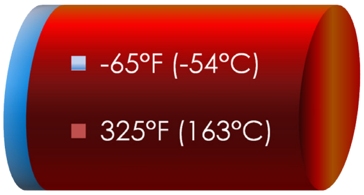
Temperature range of Fluorocarbon

FLUOROCARBON



Molecular Structure of Fluorocarbon.

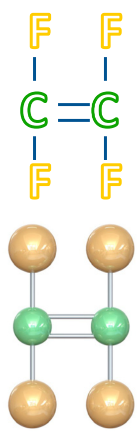
Fluorine is added to thermoset elastomers creating the Fluoroelastomers family.



Temperature Range.

Temperature range of Polytetrafluoroethylene.

POLYTETRAFLUOROETHYLENE



Molecular Structure of Polytetrafluoroethylene

Polytetrafluoroethylene (PTFE) is commonly known as Teflon.

POLYTETRAFLUOROETHYLENE or FEP or PTFE or TEFLON

High cost, temperature -65° to 325°F

ASTM D2000/ SAE J200 Type/Class

ASTM D1418 Designation FEP

Shelf life Unlimited

Polytetrafluoroethylene, also commonly known as Teflon®, is known for its non-reactive characteristic. The strength between the bonds of carbon and fluorine gives the material this non-reactive characteristic. It is widely used in a lot of industries because it has one of the lowest coefficients of friction against any solid.

Advantages: Great chemical resistance. Can be used in petroleum oils and fuels, ozone, chemical applications, solvents (MEK, acetone, xylene), and weather. It is used in high speed and pressure applications; and in applications where lubricants cannot be used. Known for it's low friction properties.

Disadvantages: Cannot be used in fluorine greases and oils, chlorine trifluoride, and molten alkali metal solutions. It doesn't seal well when the surface of the rod is rough or vibrates.

MATERIALS

SILICONE or VMQ or Q

Medium cost, temperature -65° to +300°F

ASTM D2000/ SAE J200 Type/Class – FC, FE or GE

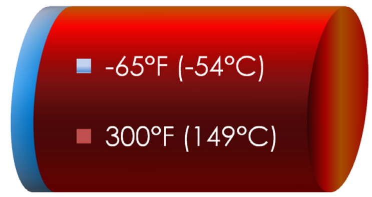
ASTM D1418 Designation MQ, PMQ, VMQ

ARP 5316 Shelf life Unlimited

Silicones are elastomers made from silicone, oxygen, hydrogen and carbon. Silicones are used in the medical and food industry because they do not have any odor or taste.

Advantages: Resistant to oxygen, ozone, UV light, mineral and vegetable oils, diluted salt solutions, engine and transmission oil, brake fluids (non petroleum base), fire resistant hydraulic fluid, high molecular weight chlorinated aromatic hydrocarbons. Good flexibility and compression set.

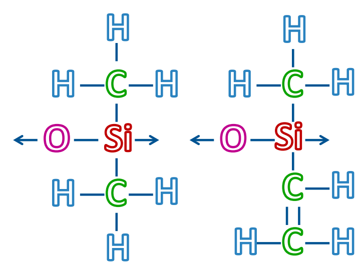
Disadvantages: Cannot be used in acids, EP fluids, fuels, gear oils, ketones and benzene. Should not be used in dynamic applications due to it's low tensile strength, poor wear and tear strength.

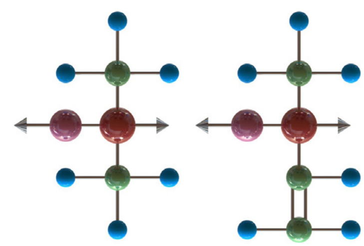


Temperature Range.

Temperature range of Silicone.

SILICONE

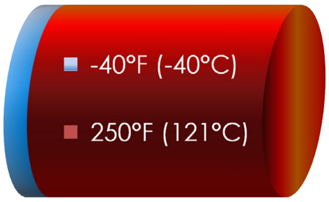




Molecular Structure of Silicone.

Are elastomers made from silicone, oxygen, hydrogen and carbon.

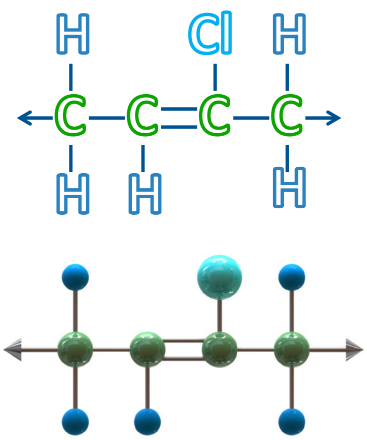
MATERIALS



Temperature Range.

Temperature range of Chloroprene Rubber.

CHLOROPRENE



Molecular Structure of Chloroprene

First synthetic rubber developed commercially.

CHLOROPRENE RUBBER or CR or Neoprene®

Temperature -40° to 250°F

ASTM D2000/J200 Type/Class BC, BE

ASTM D1418 Designation CR

ARP 5316 Shelf life 15 Years

Chloroprene is the first synthetic rubber developed commercially and exhibits generally good ozone, aging and chemical resistance. It has good mechanical properties over a wide temperature range.

Advantages: Can be use in paraffin base mineral oil with low DPI, silicone oil and grease, water and water solvents (up to 250°F), refrigerants, ammonia and carbon dioxide.

Disadvantages: Cannot be used with aromatic hydrocarbons, chlorinated hydrocarbons, ketones, esters and ethers.

EPDM or ETHYLENE PROPYLENE DIENE MONOMER

Temperature -70° to 302°F

ASTM D2000/J200 Type/Class AA, BA, CA, DA

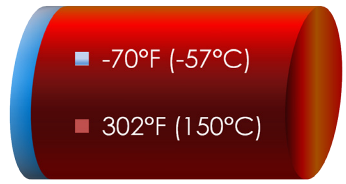
ASTM D1418 Designation EPDM

ARP 5316 Shelf life Unlimited

Ethylene propylene diene monomer is also known as EPDM, the E stands for ethylene, P for propylene, D for Diene and M for monomer. The ethylene content is typically around 45% to 75% for the EPDM.

Advantages: Can be used in water and steam (up to 300°F), glycol based brake fluids, silicone-based break fluids, many organic and inorganic acids, cleaning agents, sodium and potassium alkalis, phosphate-ester based hydraulic fluids, silicone oil and grease, alcohols, ketones, esters and ozone.

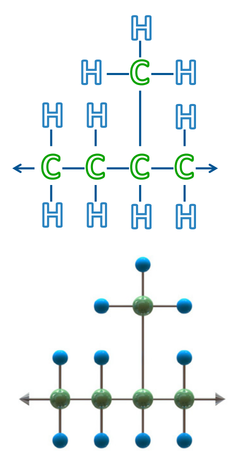
Disadvantages: Cannot be used with mineral oil products like oils, greases and fuels.



Temperature Range.

Temperature range of Ethylene Propylene Diene Monomer.

EPDM

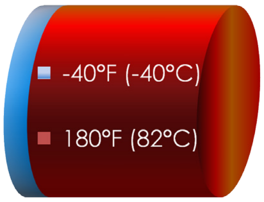


Molecular Structure of Ethylene Propylene Diene Monomer

The E stands for ethylen, P for propylene, D for diene and M for monomer.

MATERIALS

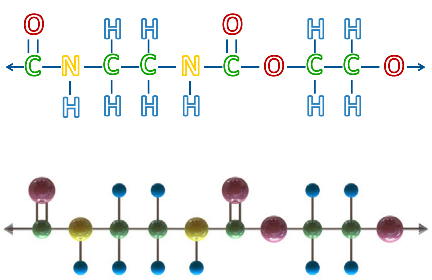
POLYURETHANE or AU or EU



Temperature Range.

Temperature range of Polyurethane.

POLYURETHANE



Molecular Structure of Polyurethane

The essential components of Polyurethane are isocyanate and polyol.

Temperature -40°F to 180°F

ASTM D2000 /J200 Type/Class BG

ASTM D1418 Designation AU, EU

ARP 5316 Shelf life 5 Years

Polyurethanes are produced by the polyaddition reaction of a polyisocyanate with a polyol in the presence of a catalyst.

Advantages: Good wear resistance, high tensile strength, tear strength, extrusion resistance and elasticity. Can be used with propane, butane, mineral oil and grease, silicone oil and grease.

Disadvantages: Cannot be used with ketones, esters, ethers, alcohols, glycols, steam, alkalis, amines, acids. Water resistant capable but only up to 125°F.

MATERIALS

CASE MATERIALS

The material of the metal case can be carbon steel or stainless steel depending on the customers requirements. Other materials such as aluminum and brass are available but seldom used due to their additional cost.

Some factors that determine the material of the case are the bore material, the fluid that its used and the environment that the case is exposed to.

CARBON STEEL

According to The American Iron and Steel Institute carbon steel is defined as having no more than 2% carbon and no other appreciable alloying elements. In seal constructions it is used as a general purpose case material.

There are many grades of steel available but for seal case construction low carbon steel is extensively used. Low carbon steel generally has 0.04% - 0.15%, carbon content. It is also known as mild steel and has a low tensile strength and is well suited for installating into metal bores.

CARBON STEEL	
Low Carbon	0.04% - 0.15%
Medium Steel	0.3% - 0.6%
High Carbon	More than 0.6%

STAINLESS STEEL

Used for its corrosion resistance properties, it is non-magnetic and contains sufficient chromium to form a passive film of chromium oxide, which prevents further surface corrosion and blocks corrosion from spreading into the metals internal structure. The FDA requires that the seals being used in drug and food preparation have a stainless steel case.

Metal Case.

The material of the case can be carbon steel or stainless.

SPRING MATERIAL

The spring of the seal is made of mid-high carbon steel or spring steel which contains 0.6 to 0.9% carbon. This material is known to have very high yield strength which allows the material to return back to it's original shape after significant bending or twisting.

Stainless steel is a second choice for spring material and can be used in high temperature applications or in corrosive environments.

The FDA also requires that for seals used in food and drug preparation the spring must be a stainless steel material.

Garter Spring.

Commonly high carbon spring steel.

ASTM D 2000

The American Society of Testing and Materials established the ASTM D 2000/ SAE J200 the “Standard Classification System for Rubber Products in Automotive Applications”.

This classification is used to ensure that besides the different compounds manufacturers are using, the quality and performance of the material is consistent.

This line call-out contains the following:

ASTM D2000-12 M 2 BG 7 14 B14 EA14 EF11 EF21 EO34

- Suffix Requirement Tests
- Tensile Strength
- Hardness
- Class (Oil resistance)
- Type (Heat resistance)
- Grade Number
- Metric Unit
- Revision year

- The document name. The two digit number following ASTM indicates the revision year.

ASTM D2000-**12** M2 BG 7 14 B14 EA14 EF11 EF21 EO34

Revision Year

- The letter M indicates units are SI, when it’s not present the units are in English units.

ASTM D2000 **M**2 BG 7 14 B14 EA14 EF11 EF21 EO34

Metric Unit

- The Grade Number defines specific added test requirements in cases where the basic requirements do not always sufficiently ensure an acceptable material. A grade of 1 indicates that only the basic requirements need to be met. A grade of 2 or above indicate additional tests are required for the material.

ASTM D2000 M **2** BG 7 14 B14 EA14 EF11 EF21 EO34

Grade Number

- The Type indicates the heat resistance properties of the elastomer.

ASTM D2000 M 2 **B**G 7 14 B14 EA14 EF11 EF21 EO34

Type

TYPE	TEST TEMPERATURE ° C	° F
A	70	158
B	100	212
C	125	257
D	150	302
E	175	347
F	200	392
G	225	137
H	250	482
J	275	527
K	300	572

- The class indicates the swell resistance properties of the elastomer as measured by volume swell under test procedures.

ASTM D2000 M2 B**G** 7 14 B14 EA14 EF11 EF21 EO34

Class

CLASS	VOLUME SWELL (Maximum %)
A	No requirement
B	140
C	120
D	100
E	80
F	60
G	40
H	30
J	20
K	10

The table below has the most common polymers used for type and class:

AA	Natural rubber, reclaimed rubber, SBR, butyl, EP, polybutadiene, polysoprene
AK	Polysulphides
BA	Ethylene propylene, high temperature SBR, butyl compounds
BC	Chloroprene polymers (neoprene), CM
BE	Chloroprene polymers (neoprene), CM
BF	Nitrile
BG	Nitrile, urethanes
BK	Nitrile
CA	Ethylene propylene
CE	Chlorosulfonated polyethylene (Hypalon®), CM (Chlorine)
CH	Nitrile, epichlorohydrin polymer (Hydrin®)
DA	Ethylene propylene polymers
DE	CM (Chlorine), CSM (Chlorosulfonyl)
DF	Polyacrylate (butyl-acrylate type)
DH	Polyacrylate polymers, HNBR
EE	AEM, ethylene acrylic, (Vamac®)
EF	Ethylene acrylic, Vamac®
EH	ACM (polyacrylate)
EK	Float zone silicone (FZ)
FC	Silicone (high strength)
FE	Silicones
FK	Fluorosilicone
GE	Silicones
HK	Fluoroelastomers (Viton®, Fluorel)
KK	Perfluoroelastomers

- The next digit is the hardness of the elastomer, measure in the Shore A durometer.

ASTM D2000 M2 BG **7** 14 B14 EA14 EF11 EF21 EO34

Grade Number

- The next two digits indicate the minimum tensile strength. If it's in the metric units it will be in MPa (megapascals); and if it's in the English unit it's in ksi (kilopounds-per-square inch).

ASTM D2000 M2 BG 7 **14** B14 EA14 EF11 EF21 EO34

Tensile Strength

- Suffix requirement tests: the letters and numbers after the tensile strength indicates the additional test that are required. The letter indicates the test, the first digit indicates the test method and the second digit indicates the temperature. The tests required vary depending on the first digit after the suffix letter.

ASTM D2000 M2 BG 7 14 **B**14 **EA**14 **EF**11 **EF**21 **EO**34

Suffix Requirement Test

MATERIALS

- The table below shows the various tests required, with the first suffix letter listed down the side and the first suffix number listed across the top.

Basic Requirements and First Suffix No. Requirement or Suffix Letter	Basic	1	2	3	4	5	6	7	8	9
Tensile Strength, Elongation	D412, die C	-	-	-	-	-	-	-	-	-
Durometer Hardeness, Type A	D2240	-	-	-	-	-	-	-	-	-
Suffix A, Heat Resistance	-	D573,70h	D865,70h	D865,168h	D573,1000h	D865,1000h	-	-	-	-
Suffix B, Compression Set, Standard Test Specimen Cut from a Slab	-	D395,22h, Method B, solid	D395,70h, Method B, solid	D395,22h, Method B, plied	D395,70h, Method B, plied	D395,1000h Method B, solid	D395, 1000h, Method B, plied	-	-	-
Suffix C, Ozone or Weather Resistance	-	D1171, ozone exposure, Method A	D1171, weather	D1171, ozone exposure, Method B	-	-	-	-	-	-
Suffix D, Compresion-Deflection Resistance	-	D575, Method A	D575, Method B	-	-	-	-	-	-	-
Suffix EO, Oil Resistance	-	D471, ASTM Oil No. 1, 70h	D471, ASTM Oil No. 2, 70h	D471, ASTM Oil No. 3, 70h	D471, ASTM Oil No.1, 168h	D471, ASTM Oil No.2 168h	D471, ASTM Oil No. 3, 168h	D471, Service Fluid No. 101, 70h	D471, Oil as specified with ASTM	-
Suffix EF, Fluid Resistance	-	D471, Reference Fuel A, 70h	D471, Reference Fuel B, 70h	D471, Reference Fuel C, 70h	D471, Reference Fuel D, 70h	D471 Volume Percent Reference Fuel D Plus 15 Volume Percent Denatured Ethanol, 70h	-	-	-	-

Basic Requirements and First Suffix No. Requirement or Suffix Letter	Basic	1	2	3	4	5	6	7	8	9
Suffix EA, Aqueous Fluid Resistance	-	D471, Distilled Water, 70h	D471, Equal Parts by Volume Distilled Water-Reagent Grade Ethylene Glycol, 70h	-	-	-	-	-	-	-
Suffix F, Low-Temperature Resistance	-	D2137, Method A, 9.3.2, 3 min	D1053, 5min, T_2 T_5 T_{10} T_{50} or T_{100}	D2137, Method A 9.3.2, 22h	-	-	-	-	-	-
Suffix G, Tear Resistance	-	D624, die B	D624, die C	-	-	-	-	-	-	-
Suffix H, Flex Resistance	-	D430, Method A	D430, Method B	D430, Method C	-	-	-	-	-	-
Suffix J Abrasion Resistance	-	-	-	-	-	-	-	-	-	-
Suffix K Adhesion	-	D429, Method A	D429, Method B	Bond made after vulcanization	-	-	-	-	-	-
Suffix M, Flammability Resistance	-	-	-	-	-	-	-	-	-	-
Suffix N, Impact Resistance	-	-	-	-	-	-	-	-	-	-
Suffix P, Staining Resistance	-	D925, Method A	D925, Method B Control Panel	-	-	-	-	-	-	-
Suffix R, Resilience	-	D945	-	-	-	-	-	-	-	-
Suffix Z, Special Requirement	-	-	-	-	-	-	-	-	-	-

MATERIALS

- Lastly, the second suffix number indicates the test temperature required.

ASTM D2000 M2 BG 7 14 B**14** EA**14** EF**11** EF**21** EO**34**

Suffix Requirement Test

Suffix Letters A, B, C, EA/F/O, G, K, L	
1	73° F / 23° C
2	100° F/38° C
3	158° F/70° C
4	212° F/100° C
5	257° F/125° C
6	302° F/150° C
7	347° F/175° C
8	392° F/200° C
9	437° F/225° C
10	482° F/250° C
11	527° F/275° C

Suffix Letters F	
1	73.4° F/23° C
2	32° F/0° C
3	14° F/-10° C
4	-0.4° F/-18° C
5	-13° F/-25° C
6	-31° F/-35° C
7	-40° F/-40° C
8	-58° F/-50° C
9	-67° F/-55° C
10	-85° F/-65° C
11	-103° F/-75° C
12	-112° F/-80° C